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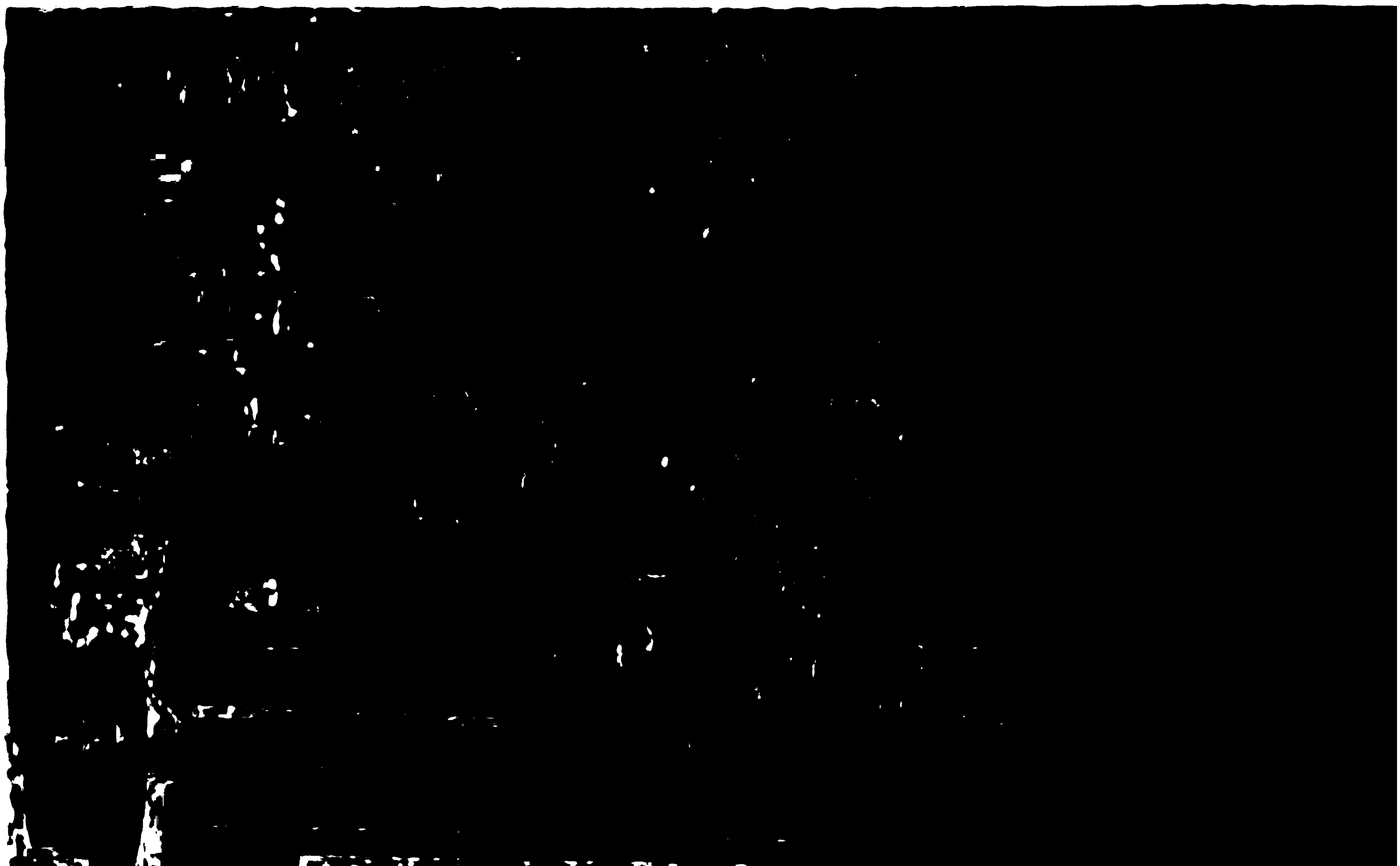

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THE HISTORICAL DEVELOPMENT OF MODERN MACHINE TOOLS

BY

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A THESIS SUBMITTED FOR
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In working up the material for this thesis, the subject was divided into two parts, one to include lathes, the other to take all other machine tools. A large number of manufacturers of machine tools were written to and asked for any references which they might know of that would have any bearing on the subject. In this way, some very valuable material was obtained. By far the greatest amount of material was found to relate to the lathe. To many tools no reference was made. Thus a rather complete history of the development of the lathe is given, but the development of the other tools could not be fully traced.

The greater share of the material on lathes was obtained from The Jones & Lamson Machine Company, R. E. Flanders, Advertising Manager; T. S. Bentley, Rivett Lathe Company; Rees' Encyclopedia; American Machinist.

References relating to the history of other tools were obtained from the following:

Modern Industrial Progress -- Chas. H. Cochrane.
Machine Shop Practice -- F. W. Turner.
Milling Machines and Milling Practice--D. DeVries.
Modern Milling Machines -- Joseph G. Horner.

and the following articles:

How Machine Tools are Developed--John Randal in The American Machinist.

The Progress of the Mechanical Arts in three-fourths of

a Century--Coleman Sellers in The American Machinist.

Improved Turning Lathe--Dr. J. P. Jones in the Journal of the Franklin Institute.

All machine tools are so closely allied that the lathe is the only one that admits of separate treatment. The rest depend largely upon the lathe and upon each other and this inter-dependence makes individual handling difficult.

The following as to what is and what is not a machine tool was written by Mr. T. S. Bentley.

"The question as to what is and what is not a machine tool has been exciting no little discussion of late and the controversy has shown how widely opinions differ as to what machines may be properly so described and what should be put into another category. The matter is of more than academic interest as the term is of such importance and so constantly used that a clear definition is certainly desirable. Many suggested definitions have been put forward and many diverse views expressed with regard to the question. The word machine has been so far specialized that in place of meaning any mechanical aid it now conveys the idea of a more or less complex piece of mechanism designed to transmit, transform or apply power in order to achieve some desired result. In like manner the word tool has gone thru a

scale of meanings and in a broad sense is applied alike to the simplest hand instrument and to some of the most complex machines which equip the modern machine shop. In general, however, the word tool signifies a small appliance for the performance of almost any simple operation. A hammer is a tool for striking; a file for smoothing; and a needle for sewing. Altho tools or mechanical aids are employed by every one more or less, they are not always known by that name and it is interesting how they have been grouped by common usage under distinctive titles. Thus in work shops they are tools; in surgery and drafting, instruments; in gymnasiums, apparatus, and in the kitchen, utensils. The word tool covers them in its broadest sense. There have been many definitions suggested with the view to restricting the applicability of the term machine tool. On comparing them we discover that they not only differ in phase, but differ still more in the ideas which underly them. Some lay stress on the characteristics of the machine itself and others on the kind of work which can be done on it, but most of them base their classification on the kind of work the machine actually performs, others make their classification dependent on the purpose for which the work is produced."

Let us consider a few suggested definitions and the criticism thereof.

(A) A machine tool is a machine used in the building of

other machines.

This definition is short and brief but is too wide and yet too narrow. It would let in the crane and the lifting jack while shutting out half the equipment of the tool room.

(B) A machine tool is any hand or power driven mechanism consisting of several parts, some of which move to perform any process or operation in making tools, machines structures, and the parts thereof from metal and other alloys, and which is not used in or based upon other mechanism to make it operate.

This is too long for popular adoption and does not appear to do what is intended after all. The steam hammer would come under its scope but most of the portable tools which form so useful a feature in many modern shops would seem to be ruled out.

(C) A machine tool is any hand or power driven mechanism actuating cutters, tools, dies or other forming shop implements, to perform any process or operation in making tools, machines, structures or any parts thereof from metals in distinction from one for producing a special or specific article.

This is too long for convenient use even if it adequately meets every other requirement. It is not free from ambiguity and might be taken to shut out the automatic screw machine tho probably not so intended. It will be noted that

this definition lays stress on a characteristic which neither of the others refer to.

No satisfactory definition can be based on features of design or construction because the immense variety of machines to be covered would make such an attempt inadequate, since new machines are constantly being developed. For the above reason also, a list of what should and what should not be styled as machine tools would be of little value.

Definitions making the particular work on which the machine is engaged the deciding factor will not stand analysis; neither will those which regard the ultimate use to which such product is to be put as the crucial point. Two similar machines working side by side might have to be classified differently and if for amy reason the distribution of work should be reversed the classification would have to be altered. A definition must be based on something less liable to change. It must rest not on a detail but on a principle.

The disagreement as to a definition is really inherent in the way the question is put. If it were restated as follows, "Which machines should be called 'machine tools' and which should be more definitely named," the problem is changed from the negative to the positive.

From the above considerations Mr. Bentley drew the following conclusions.

(A) That whenever a machine is so modified as to be restricted to one kind of work, it should be described by a name which makes this clear, in preference to an indefinite one.

(B) That the machine tool builders should agree together as to the general adoption of such special names and their employment in all printed matter, advertising, etc.

(C) That the course would aid the natural solution of the problem by setting up an influential usage which would stand every chance of being generally followed.

Of all the machines employed by the mechanic to aid him in his work the lathe holds the honor of having been the first machine tool. Many other machine tools have been developed from it, in one way or another, for doing quicker or better the various operations that were performed on the lathe.

First, the origin of the lathe will be studied and its gradual development and evolution up to recent years will be traced.

"Turning is the art of shaping wood, metal, ivory and other hard substances into surfaces of revolution, and also of engraving figures composed of curved lines upon a smooth surface, by means of a machine called a turning lathe." This statement is found in the older records on the subject of lathes. This art of turning is of great importance as the

most delicate articles of luxury and ornament as well as machinery is produced by it. The art of turning dates from as far back as 560 B.C. and Theodorus of Samos is named by Pliny as its inventor. Long before this, the potters wheel which was the earliest and simplest form of turning machine, was in use.

On account of the immense variety of work performed on the turning machine, a great variation in their construction is necessary. The mode of operation, however, remains the same and consists merely of revolving the piece to be turned around an axis of revolution. This axis of revolutions coincides with the two points or pivots which support the revolving piece.

In England lathes were classified according to the methods which were used in driving them, and also with respect to the kind of work they were to perform. Under the first classification were the pole lathe, foot lathe, hand wheel lathe, and power lathe; under the second classification the spindle, mandrel or chuck lathe and center lathes. Another peculiar English idea is this: "Bed lathes are those used by turners in wood, and bar lathes for the best sort of metal work, and the small center lathe employed by the watch maker is known as a turn bench".

The earliest form of a lathe proper that was used for cutting or shaping wood by the action of a chisel or other

cutting tool on the rotating piece consisted of two pointed pieces of wood serving as centers and each bound to a tree and supporting the ends of the piece to be turned. On the opposite side of the tree and fixed in the same manner was a straight piece of wood which answered the purpose of a tool rest. The power for rotating the piece to be turned was obtained by attaching a cord to a flexible limb on one of the trees, winding it around the piece to be rotated once or twice and forming in its lower end a loop for the foot of the operator,who by depressing it would cause the piece to rotate,and bend the limb which would return to its original position after the operator removed the pressure of his foot from the loop and thereby cause the piece to be in readiness for another operation. This work was slow and laborious, yet from old samples of pieces produced in this manner a good quality of work could be done, considering the method used.

In the next form of lathe developed,the principle of the flexible limb was used but in a modified form. A piece of wood formed the bed of the lathe and to it was fixed the blocks forming the centers, which have ever since been known as the head stock and tail stock of the lathe. This machine appears to have been used indoors as the flexible limb was replaced by a wooden strip or pole fastened overhead and called a "lath", from which name some writers think that the

name lathe was derived. The driving cord was still wound around the piece to be turned. No mention is made of the method used in supporting the tool but it is very probable that a strip of wood was fastened to the bed for that purpose.

The next improvement in developing the lathe brings its form within the memory of the older mechanics. This lathe has a crude form of head stock and tail stock, both constructed at first of wood and the tail stock continuing to be so constructed for many years. In this form of lathe the head spindle is first found having a plain spool around which the driving cord was wound, and later on a step pulley with which a faster speed was possible for the same movement of the foot. The lower end of the driving cord was fastened to one end of a strip of wood, the other end of which was fastened to a rear leg of the lathe, the lathe being supported by legs.

The bed was formed of two pieces of timber set on edge and a short distance apart. They were properly secured at the ends. This afforded a space down thru which passed a long tennon formed upon a wooden block answering for a tail stock. This was held in any position by a wooden key passing thru it, under the bed. The early rest of this lathe is not known but somewhat later a rest of cast iron was used. Its appearance was very similar to that used by the wood turner of the presemt day.

This lathe was used for both wood and metal, the tools being held in the hand as the slide rest had not been invented.

Another style of lathe that was used mostly for small work, generally metal work, was called a "fiddle bow lathe" on account of the method of driving it. The same method of propulsion was used in this machine. In this case, instead of the resistance offered by a spring to keep the driving cord taut, it was held in that condition by a bow. Each end of the string was fastened to an end of the bow. The bed of this tool was about twelve inches long and it had about a two inch swing. The head stock and rest were formed of bent pieces of wrought iron and the spur center was formed upon the main spindle, the point being used as a center for metal work. Tools driven in this mannėr are still in use by watch makers and jewelers.

It was later found in the operation of the pole lathe that the forward motion of a heavy piece was not entirely checked when the operator raised his foot and the cutting tool was withdrawn. This led to the addition of a balance or fly wheel on the spindle shaft. Later a wrist pin was attached to the wheel and the piece rotated by a helper. The fly wheel was next located beneath the bed, directly below the head stock or pulley. A short connecting rod connected the wrist pin and a treadle, the rear end of which was fast-

ened to the rear leg of the lathe. A band was passed over the wheel and pulley. The piece to be turned was rotated by the band which passed over the pulley and fly wheel, the latter being rotated by a downward pressure applied to the treadle. This worked very well as long as the operator remained at the head stock end of the lathe. To remedy this fault one end of a strip of wood was fastened to the fore end of the treadle and the other end to the front leg at the tail stock end of the lathe. This did not work very satisfactorily as too much presure had to be applied to the added strip as the operator approached the tail stock end. This difficulty was overcome by placing the balance wheel on a shaft having two cranks in it, one on each end, the shaft being as long as the lathe. The shaft was supported by journals attached to the legs. Two connecting rods connected the cranks with two levers. The rear end of these levers were pivoted to the back side of the lathe and the front ends were connected by a strip of wood or foot board.

This was for many years the prevailing form of foot lathe and was extensively used not only for turning wood but for iron, steel and other metals as well.

Many of the old mechanics would work the entire day on this kind of a lathe. At that time a day's work was not eight, nine or ten hours but "from sun to sun" or daylight till sunset. Day after day the operators would tread these

lathes and turn out a much larger quantity of work than one would imagine possible, considering the crude tools with which they worked.

One of the disadvantages of this form of foot power lathe was the short connecting rod which increased the friction and thereby decreased the useful effect of the foot power.

Maudsley, an Englishman, made lathes of various sizes in London in about 1800.[1] His lathe consisted of a strong mahogany bench whose legs or standards were about one quarter of the length of the bench from the ends of the bench. Beyond the standards were sets of drawers to contain tools, etc. The standards supported an axle having a crank in its center and a foot or drive wheel on one end. The crank was connected to a treadle by a connecting rod, the foot wheel being used to turn the work,

The lathe itself which is fixed upon the bench consists of a triangular bar which is in line with the head stock and supports the tool rest and the tail stock. This bar is not fastened to the bench directly but is supported by two short standards which are screwed to the bench.

The mandrel or spindle is supported by two separate standards and so arranged that the pulley on the spindle shaft is directly above the foot wheel. The outside standard has a screw with a conical steel point to enter the end of the

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1. Rees' Encyclopaedia.

spindle, the other standard has a hard steel collar to receive the neck of the spindle. The spindle was turned by by a band passing over the cone pulley on the spindle and the foot wheel. On the end of the spindle beyond the collar was a screw to fix on the work to be turned.

The tail stock had a hole in it in line with the spindle. A steel pin with a conical point which fitted in the end of the stock to be turned was fitted in this hole. The steel pin was held firm by a set screw in the top of the tail stock and was made to go forward by means of a screw behind it. The tail stock could be held firmly in any position along the triangular bar by a set screw.

Attached to the tool rest slider was another short triangular bar of the same dimension but perpendicular to the main bar. Another slider supporting the tool rest was fitted upon this short bar, in this way permitting the tool to slide in a direction perpendicular to the axis of the lathe, and also parallel to the axis of the lathe. The tool rest could be made rigid in any position by means of set screws which screwed into the lower surface of the bars.

On the last named slider is a socket to receive a pin on the top of which is a cross piece formed like a T, upon which the tool was laid. The cross bar could be adjusted to the height of the work, the tool was to be applied to and was secured at any height by a screw in the side of the socket.

The work to be turned was fastened to the end of the spindle so as to be turned around with it by a chuck. The chuck consisted of hollow metal or wooden pieces, one end of which screwed into the end of the spindle and into the other end of which was driven the piece to be turned. If the piece to be turned was very long, the other end was supported by the tail stock.

With another slide rest Maudsley was able to cut threads on his lathe. This slider which was attached to the short bar had a piece of metal attached to it which ran parallel to the main bar. Thru this piece of metal and connected to the tool rest proper was a threaded bar, which, when rotated, caused the rest to travel in a line parallel to the center line of the lathe. The direction of travel depended upon the direction of rotation of the bar. On one end of this threaded bar was a spur gear which meshed with a gear on the spindle. When the spindle was rotated, and therefore the work, the tool traveled parallel to the work and if engaged with it would cut a thread. When the tool reached the end of the work it was drawn back and the machine reversed so as to bring the tool back to its original position.

In the year of 1817 Mr. Richard Roberts invented what is known as the slide rest lathe, and in 1820 he invented a screw cutting machine.[1] Roberts saw Maudsley's early screw

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[1] Engineer, October 21, 1910, page 431.

cutting machine and carried forward the principles of design learned from Maudsley.

One of the lathes can be seen in the Science Museum at South Kensington, England, and it is to be hoped that the other which is still in the possession of Beyer, Peacock & Company, may some day join it.

The saddle travels back and forth by means of a screw which runs thru it. The entire appearance of the lathe with the exception of the gearing for changing the speed is very similar to the lathe of the present day.

The change speed gear of this tool consisted of two large bevel gears with a two sided jaw clutch between them. This clutch was operated by an elaborate linkage which was so arranged that if lugs had been put on the rod they could by suitable means have caused the motion of the saddle to reverse automatically. No lugs, however, were found and since the linkage could have been greatly simplified if the reversing or stopping action of the saddle were not required, some support must be given to an old workman who said that the machine was used for cutting keyways. Since the lead screw nut is not split the quickest way to return the saddle would be by reversing the screw.

The two bevel gears ran loose on the screw stem and were driven by a third gear which meshed with them, in such a way that the gears rotated in opposite directions. The clutch

was keyed to the screw stem and by making it engage with the proper gear the saddle could be made to travel in the desired direction. The small gear was driven by a mechanism which was directly connected to the cone or step pulley. This mechanism consisted of a circular disc which was on the circular shaft with the bevel driving gear. From the surface of this disc and along the circumferences of circles of various diameters, projected small metal pins. The distance between the centers of two adjacent pins on the same circumference was equal. On the pulley shaft was a small disc having but one circle of pins. The planes of the two discs were perpendicular to each other. By properly spacing the pins they were made to mesh and thus the two discs were similar to two bevel gears. The speed of the driven gears could be varied by making the small disc pins engage with pins in a smaller or larger circle since the speed of the driver was constant.

An old workman who explained the action of this lathe describes the cutting of keyways as follows: The shaft in which the keyway was to be cut was securely fastened to the centers of the lathe and the belt was slipped off of the step pulley. The screw was driven by means of another pulley which was fastened to it. Altho this pulley was used in this way it is very probable that it was used to give a quick return to the saddle. The saddle could also be returned by

turning a small handle at one side. The handle is connected to the lead screw nut by a pair of fine toothed wheels. By turning the handle and therefore the screw nut the saddle can be brought to any desired position. When the machine is in operation a small pawl falls in one of the teeth and prevents the screw nut from turning.

The bed of the screw cutting machine is very similar to that of the sliding lathe. This machine was designed for screw cutting only. In the early days nobody thot of screw cutting and turning on the same machine, and for this reason this machine was very large and unsuitable for anything but one purpose. The general appearance of this machine is not equal to that of the sliding lathe. It also has a weak appearance due to the overhanging head stock. The saddle of this tool was made to travel by a screw the same as in the lathe.

The method of driving this tool is the reverse of that used the present day. The belt pulley is on the lead screw and the spindle is driven by means of gears. A patch plate is mounted on the spindle to permit of simple dividing when cutting multiple threads. The lead screw nut is solid and the screw must be reversed by over head motion to return the saddle. By means of a small handle on the side of the saddle the cutting tool can be quickly withdrawn from the work. The depth of the cut is adjusted by a small wheel on the

front of the saddle. Different threads can be cut by using different lead screws. Until quite recently this machine was used for cutting the reversing screws of locomotives. This machine was working side by side with machines ninety years its junior.

The following letter which was written by Mr. Richard Peacock in 1885 to Mr. S. Ford may be of some interest. Mr. Peacock is a member of the firm of Beyer, Peacock & Company, who had the above tools in their possession at this time, and Mr. Ford was curator of the Patent Museum.

Gorton Foundry, Manchester
January 15, 1885.

Richard Roberts' Lathes.

Dear Mr. Ford:

In regard to your inquiry regarding the two original lathes in the possession of my firm, I find that the slide lathe is marked "Richard Roberts' 1817".

The screw cutting machine is marked "Sharp, Roberts & Co.," but there is no date upon it. I always understood Mr. Roberts (who was an old friend of mine) to say that he made the slide lathe first and then the screw cutting lathe to suit and follow it, and the character of their design shows that they were both made at about the same time.

We had the lathes directly from Mr. Roberts himself when he gave up business, so that they have never been in other hands than his and ours, and he was particularly anxious that my late partner, Chărles Beyer--who was many years Mr. Roberts' chief assistant at the Sharp, Roberts & Company--and myself should have them, "to take care of" as he used to say.

We formerly had an old foreman named Woodcock who was with Roberts at the time these lathes were made, and he used to say that the screw cutting machine was made three years after the slide lathe, and that being so, the former would be made in or about 1820.

We received them in 1854 and they are still at work and have been ever since, doing it equally well with any tools--of their class--in our place--- I am yours faithfully,

(Signed) R. Peacock

Mr. Baxter D. Whitney was born in 1817 and acquired the trade of all around mechanic in the repair shop of his father's mill.[1] At the age of 13 he was a good enough mechanic to be sent to Worcester, Mass., to help build some looms which were being constructed for his father's mill.

In 1833 at the age of 16 he designed and made a lathe many features of which are found in the modern lathe. It has the weight type of carriage and swings 18 inches by about 6 feet. The bed, heads, carriage, steady rest, and legs were made of iron but the two beams running lengthwise from leg to leg at the bottom were made of wood. The castings were obtained from a foundry in Worcester. At this time there were no planers long enough in this neighborhood to plane the bed and since chipping and filing did not appeal to Whitney he used a scheme of his own. He laid the bed on the floor with a heavy beam of wood on each side of it. These were planed up true and lined up with each other and the bed. A traveling carriage was then fitted to the wooden beam and on this was mounted a milling spindle carrying cutters to finish the Vs,the casting in between the Vs being left rough.

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[1] American Machinist, Volume 31, page 317.

The carriage of the lathe at the front rides on a round topped way and at the back a shoe travels on the flat top of the way or more properly rib which runs from end to end of the top of the bed of the lathe. The shoe is provided with two vertical pins which run up thru two holes in the carriage. An elevating screw impinges on the top of the shoe. The idea of rounding the top of the front V was so that the rounded groove in the under side of the front of the carriage would find a seat with the back of the carriage elevated or depressed.

The carriage was fastened to one end of a rack, the other end of which extended beyond the headstock end of the lathe.

The tail stock steady rest and head stock rest on the inner ways, the tops of which are flat. The feed mechanism was driven by a belt from a two step cone at the rear end of the spindle. In front of the bed and running from end to end are two rods. The upper one was provided with single ended ball levers. By rocking this rod by means of these levers, the direction of the motion of the carriage may be reversed. When in mid position the carriage could be moved by hand. A hook shaped flat spring kept the levers from shifting during operation. The rack to which the carriage was attached, meshed with a spur gear which was connected to the feed mechanism. This rack projected beyond the lathe a

distance equal to the length of the cutter when the carriage was at the head stock. In this way the carriage was made to go back and forth.

In about 1860 a peculiar form of lathe was built in the railroad shops at Plattsburgh, N. Y. This was an engine lathe of about fourteen inches swing, built with cast iron legs and all the parts were made of metal that are now so constructed. Instead of placing the large driving or balance wheel beneath the lathe, as was done in previous machines, it was attached to the ceiling. Attached to this wheel was a step pulley. The wheel and pulley were fastened to a shaft which was as long as the bed of the lathe. The step pulley was directly above the step pulley of the lathe and connected to it with a belt. The method used to drive this tool was very similar to the methods formerly used. The mechanism consisted of two treadles which were pivoted to the rear legs of the lathes and on the outside thereof, instead of the inside, as had previously been done. The front ends of the treadles were connected by a strip of wood. One end of the shaft carried a fly wheel, into the hub of which was fixed a stud or wrist pin, the other end carried a disc having a similar stud. These formed two cranks to which were fitted two long connecting rods, the lower ends of which were connected to the front end of the treadles. The weight of the connecting rod, treadles and wooden strip was counter-

balanced by a weight added to the rim of the flywheel. This lathe ran with a good deal of power and its general performance was better than that of previous tools. The momentum of the flywheel pulleys and shaft was very beneficial in maintaining a constant speed, under varying conditions of resistance due to the cutting tool. This machine had one disadvantage, in that too much time was consumed in bringing it up to speed and too much time was consumed in stopping it, as no provision was made for disconnecting the main spindle from the driving pulley, as with a clutch mechanism, which is one form of mechanism used at the present day.

In the year 1871 in the village of Brattleboro, Vermont, the first automatic screw machine was made.[1.] The inventor and maker of this machine was Francis Curtis, a cabinet maker born in Canada, where he lived until 1865, when he came to the above village in Vermont.

He had a shop of his own in which he made spindle bedsteads, which were so popular at that time, and other furniture. Curtis always had an inclination to tinker with machinery, and he was very anxious to take up this line of work in preference to cabinet making.

He succeeded in accumulating $1000 besides paying for his home. Part of his savings was invested in machinery which consisted of a planer, an engine lathe and a speed lathe. With the above tools he set about making velocipedes.

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1. Letter from Mr. T. S. Bentley.

He built a certain number and decided not to build another lot until the first lot was sold. Before he started the second lot his plans were diverted by a remark made to him by a man for whom he was doing some work. This man picked up a screw from off of a bench in Curtis' shop, and after looking at it for a moment said, "Frank, why don't you make a machine for making these screws automatically". "I can and I will", replied Mr. Curtis. He went about to plan the machine at once with the result that within eleven months after it had been suggested, he had a complete machine finished and running. This tool proved to be one of the greatest labor saving devices of the 19th century. The machine was built without drawings, with the exception of a few sketches of some of the details. He had some difficulty to overcome which he did without any assistance from anyone.

The machine had a hollow spindle upon which was a pulley for driving it. An inner tube fed wire up to certain lengths. A three jawed chuck held the wire as it rotated. The box tool of this machine traveled in a longitudinal direction, while a carriage with two spindles,one holding a screw die and the other a chuck traveled in a transverse direction.

The action of the tool is as follows: The box tool approaches the stock which is rotating with the three jawed chuck, and cuts the stock down to the body size of the screw. After the box tool returns to its original position the

carriage approaches from the front of the lathe until the screw die is in line with the screw blank. An arm then pushes the die onto the blank and the thread is cut to the required distance. The die then revolves with the spindle until the cutting off tool which is already in the act of cutting off the blank finishes doing so. The carriage then travels away from the front of the lathe until the die is in line with the header. This header which also travels in a longitudinal direction, but is on the opposite side of the carriage, approaches the die, cuts the head on the blank, and then returns to its original position. The carriage again travels away from the front of the lathe until the die is in line with the screw driver. Before the threaded screw reaches the driver it passes a saw or slotter which is mounted on a vertical shaft. This saw cuts the slot in the head of the screw.

The blade of the screw driver which is in line with the saw passes, into the slot cut in the screw head and by means of flexible springs attached to it, removes the screw from the die by rotating the screw. While these last operations are being performed on the screw, the box tool is cutting the stock for the second screw and it backs off in time to permit the die, after having given up the finished screw to the driver, to again get in line with the screw blank to cut another thread. While the threads are being cut on the second screw

blank, the chuck on the carriage receives the screw from the driver. By the time the second screw reaches the header, the first screw is pushed out of the chuck into a pan and is free from chips.

With this machine, screws were made at the rate of one thousand to three thousand per day. When the end of the stock of which the screws were made passed out of the wire feed, the machine stopped automatically, and rang a bell to notify the operator that a new bar of stock was required. The machine was made to take in one half inch stock, and make a screw up to one and one quarter inches long. Either round, flat, or filister head could be cut with the header. The several spindles were driven by a chain of spur gears, the slotting shaft by miter gears, and the cam shaft with a worm gear, all of which were made by Curtis himself in his shop.

One of these screw machines was at the Centennial Exposition held in Philadelphia in 1876 and another at Paris in 1878, at both of which the highest award was secured, together with special mention in the record.

In 1884 in Boston, Mass., Mr. Ed. Rivett, who was a skilled mechanical engineer, made a small, fine, accurate lathe with which scientists and advanced mechanics could make pieces which up to this time were laboriously and inaccurately performed with hand tools.[1] Rivett No. 3 is a cut of

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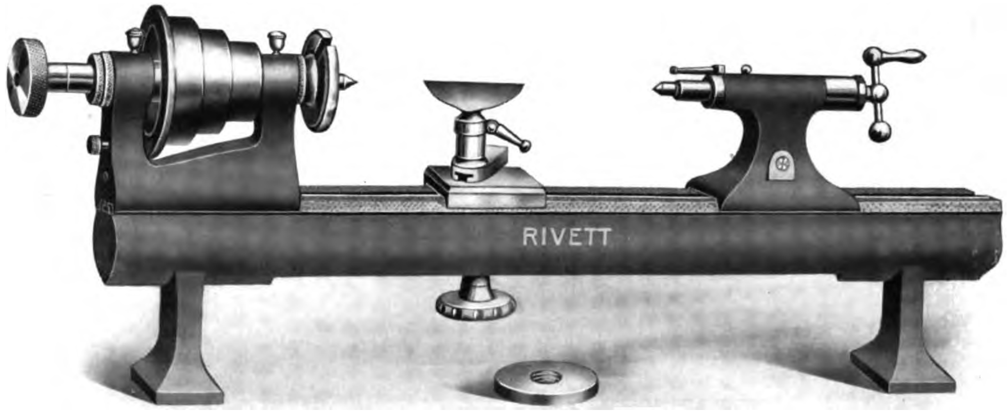
[1] Letter from Rivett Lathe Company.

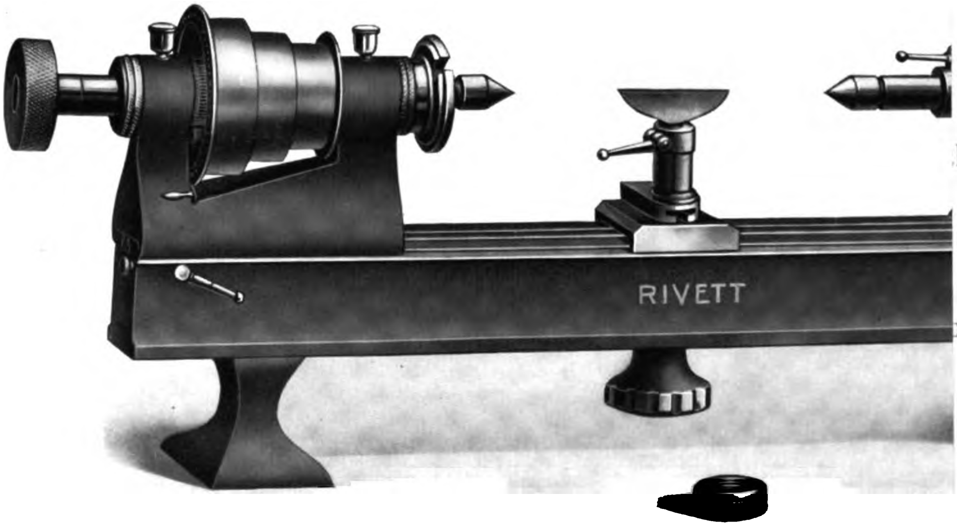
this lathe. This machine has a hardened spindle and bearing in the headstock, and also a hardened and ground tail stock spindle. The length of the bed is 32" and the swing is 7". The distance between centers is 18", the hole thru the spindle is 19/32" and its largest size of spring chuck is 13/32". The weight of the machine as it appears in the cut is ninety five pounds.



Rivett No. 3 Bench Lathe

The Rivett No. 4 as shown in the cut was made in 1890 and weighs about one hundred and forty pounds. This tool was modeled after tool No. 3 and it is especially adapted to the use of tool makers, model makers, and electricians. Split or spring chucks were made for this lathe, holding from 1/64" to 1/2" stock. The draw bar is hollow, enabling stock of any length to be run thru the live spindle. The three step cone is made for a 1-1/4" belt and the large

flange on the pulley is drilled as an index plate. The bed, feet and all parts of the lathe are milled with forming cutters, scrape finished and polished leaving no skin of casting to cause unequal strain and false alignment. The length of the bed is 36" and the swing is 8". The distance between centers is 18" and a 3/4" hole runs thru the spindle.



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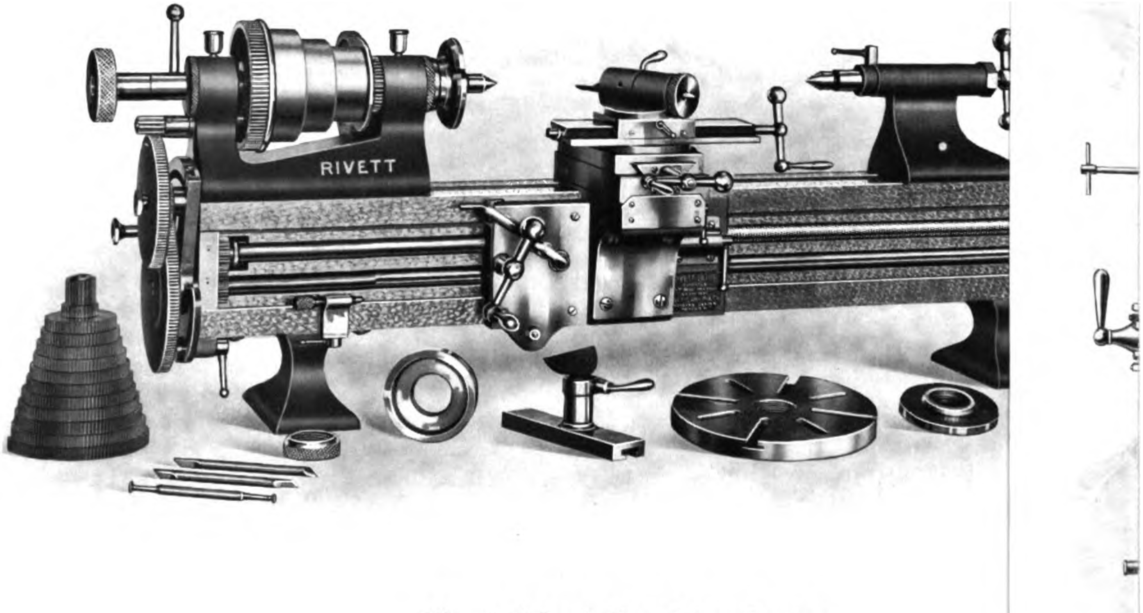
Rivett No. 4 Bench Lathe

Between the years 1890 and 1898 the Rivett 8" Precision lathe was introduced. The cut shows the lathe as it appeared in 1912. With this machine a great number of operations, starting with plain turning, can be performed. All Precision lathes are back-geared, which gives them a variety of speeds necessary to turn work varying in diameter from 8" to a few thousands of an inch in diameter. The lathe bed is 40" long,

distance between centers is 32" and it has an 8-1/2" swing. The cone is the reverse of that of an ordinary engine lathe leaving the casting strong at the thrust bearing end. The bearings are not boxes of iron or softer alloys with caps to tighten until the journals are worn out, and out of alignment, but are cylindrical in form, made of tool steel and are made as hard as possible, then ground with diamond to a perfect fit. The carriage is gibbed to the side of the bed, the V being internal and out of the way of chips. The weight of this lathe is about two hundred and fifty pounds.



Rivett 8-Inch Precision Lathe

The lathes manufactured at the present are practically built on the same principles. One will detail a certain

part more than another upon which feature the company will dwell when selling its product. The general appearance of most modern engine lathes is similar. In some designs step pulleys are not used, but a set of gears, which are incased, are used to drive the spindle,the speed of which can be changed by manipulation of levers. The gears may be either driven by a motor which is directly connected, or by a belt which passes over a pulley at the head stock end of the lathe. The feed is regulated by a second set of levers. As many of the rotating parts as possible are surrounded by a casing to protect the operator, as well as to keep dirt and dust off of the engaging surfaces of the machine elements. The body of the tail stock and carriage are heavier and the latter is wider than those of the earlier lathes. Altho the general appearance of modern lathes has been greatly modified, the principles of operation have not been altered to a great extent.

Figure 1 shows what is, so far as we know, the first turret lathe ever built with an automatic revolving turret. This machine was built by this company under the old firm name of Robbins & Lawrence, about 1857. The turret revolved automatically with the backward motion of the slide, and it was somewhat hexagonal in form, the locking pin operating from the top instead of the under side of the turret.[1]

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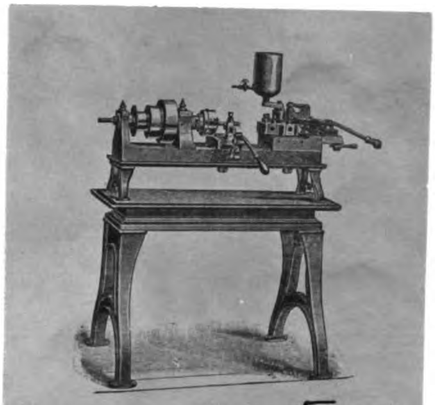
[1] Mr. R. E. Flanders, of Jones & Lamson Machine Company.



1857 Fig 1

Figure 2 shows the next development of the machine, in which the locking pin was located under the turret, as in present day practice. This machine was designed by Mr. H.D. Stone of the Jones & Lamson Machine Company in 1858. This was the first turret lathe, or screw machine, made for sale of which we have any knowledge. It was put on the market about 1861.

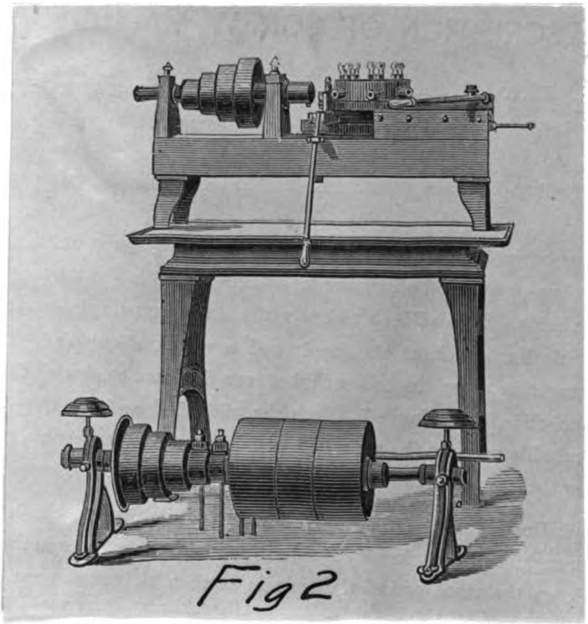


Fig 2

Figure 3 shows the next development of the machine in which the weight style of wire feed is used combined with quick opening chuck which could be operated by hand, without stopping the spindle. The patent dates on this machine are, for the chuck January 30, 1873, and for certain other features of the machine October 20, 1874. The construction of the chuck itself is shown in Figure 4. So far as we know this is the first adjustable wire feed chuck which could be operated while the machine was running.

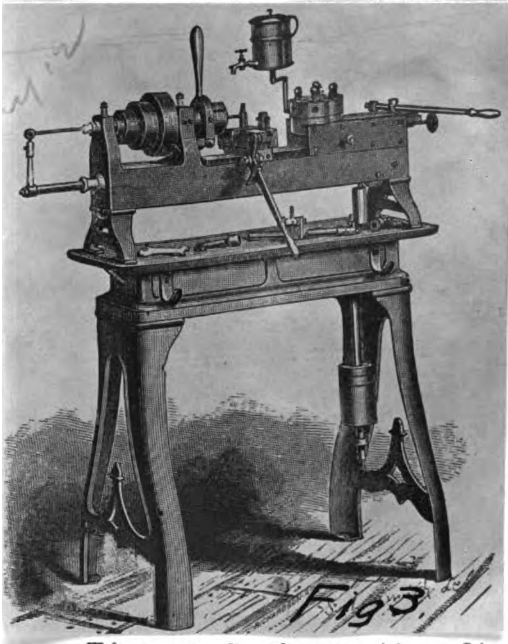


Fig 3.

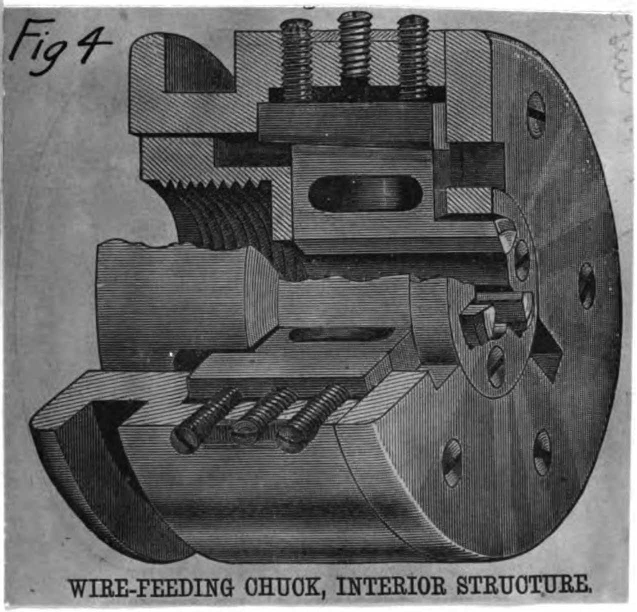


Fig 4

WIRE-FEEDING CHUCK, INTERIOR STRUCTURE.

Figure 5 shows the first application of the Power Feed to the screw machine. This was patented by the Jones & Lamson Machine Company October 20, 1874. The regular lathe back gears have been for the first time applied to the head stock.

Fig. 2.

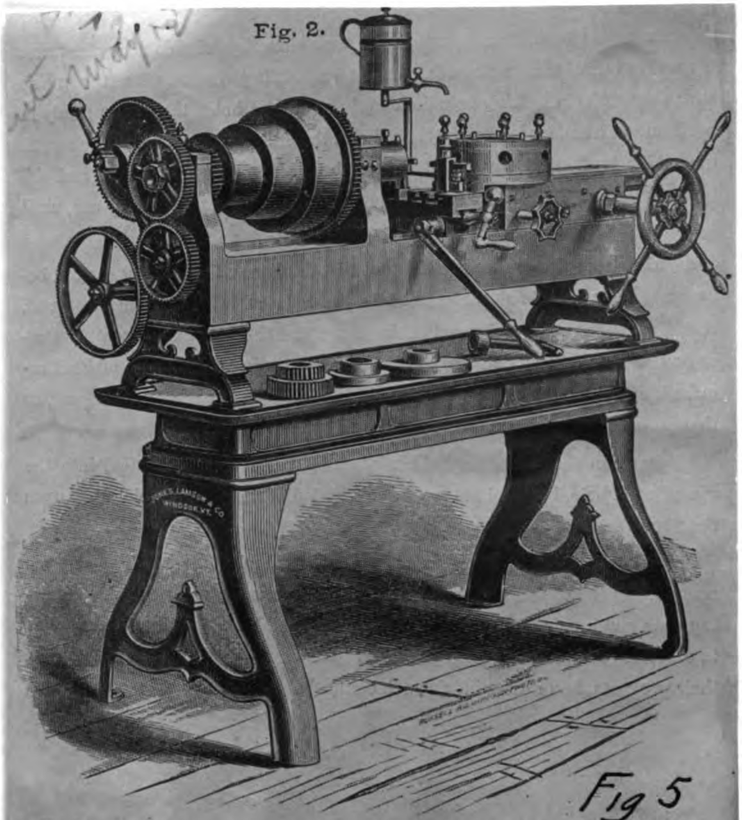

JONES, LAMSON & CO. WINDSOR, VT.

Fig 5

No. 11. BACK GEARED SCREW MACHINE WITH POWER FEED.

Patented October 20, 1874.

Length of Bed, 4 ft. 3 in. Swing over ways, 14 in. Weight, 1,600 lbs. Hole in Spindle, 1 7-16 in. Holes in Turret, 1¼ in. Diameter of Turret, 9½ in. Length it can Mill, 7 in. Size of Counter Pulleys, 13 in. diameter, 3 in. face. The speed of countershaft should be 175 revolutions per minute.

PRICE, COMPLETE, ... $ 650
PRICE, WITHOUT POWER FEED, . . 575.

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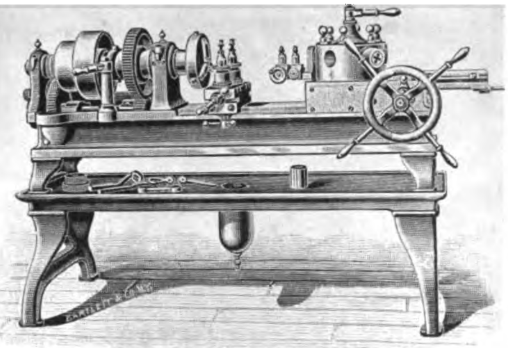
Figure 6 shows the first clutch back geared machine regularly placed on the market, which was done in 1882. In this machine for the first time the back gears could be thrown in without stopping the machine. The gearing as shown is located beneath the spindle.



1882 Fig 6

Figure 7 shows the development of the screw machine or turret lathe, as it became standardized during the eighties. All the various features previously described are incorporated in this design of screw machine substantially as it exists to-day in its conservative form.

WITH CLUTCH BACK GEARS AND POWER FEED.

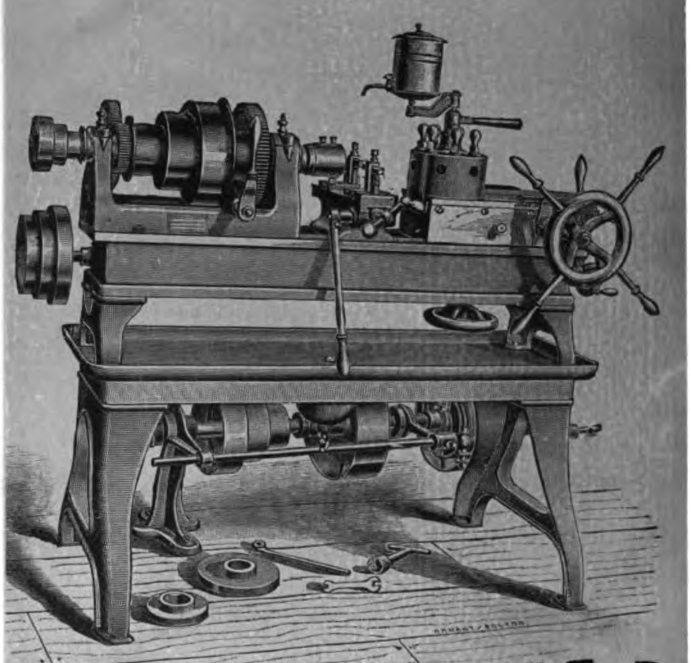


Fig 7

Figure 8 shows a design of about the same period, which includes all the refinements which had been added to the machine at that time. These improvements consist in geared power feed, chasing attachment, forms for taper turning and taper threading, improved forms of tool holders for the turret, etc. A machine similar to this with 3-1/4" hole in the spindle and with a swing of 24" was built by the Jones & Lamson Machine Company and was for a long time the largest screw machine built anywhere.

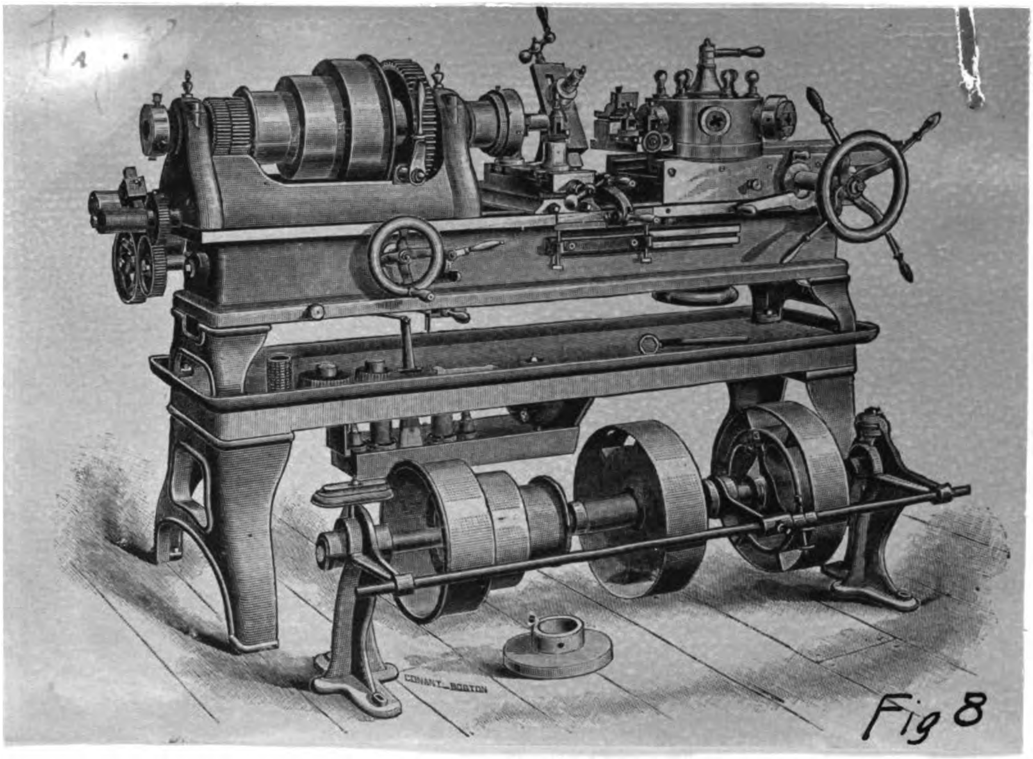


Fig 8

Figure 9 shows the first work of Mr . Hartness in improving on the traditional screw machine. Here we have a head stock which was identical in all important respects with the head stock of the Flat Turret Lathe as it was known

for so many years. The improvement consisted in the provision of the quick acting power roller feed for heavy bar stock, and an automatic chuck. The design of this roller feed and automatic chuck remains substantially unchanged in the Flat Turret Lathe of to-day. This head stock was devised in 1890.

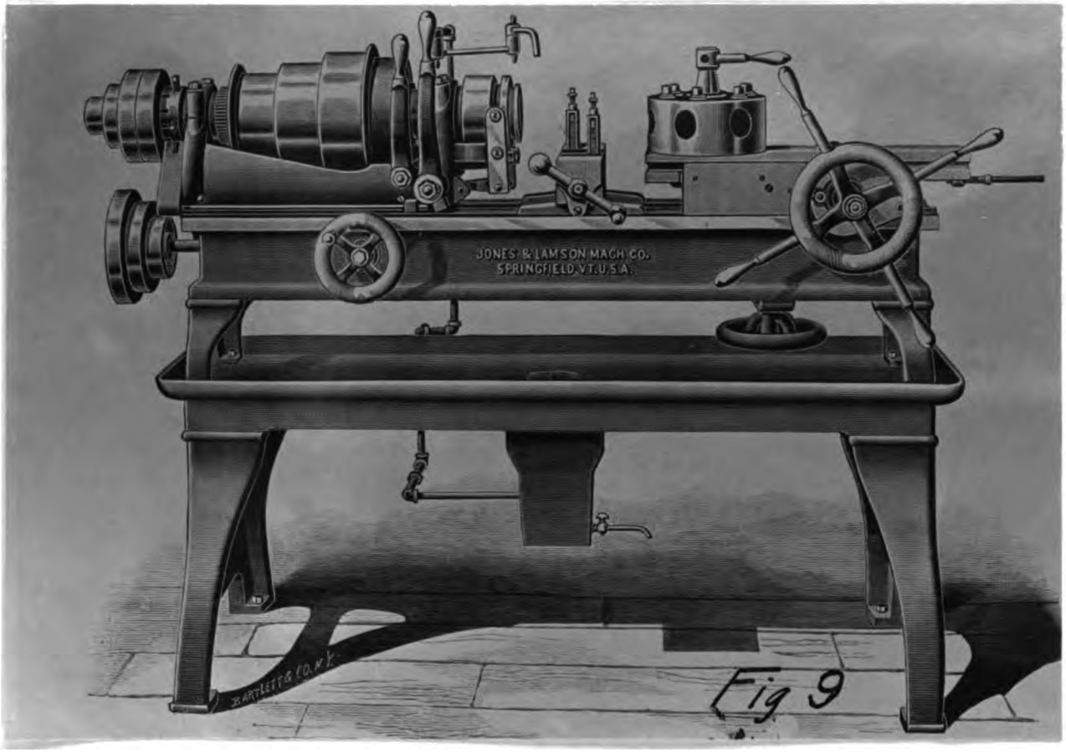
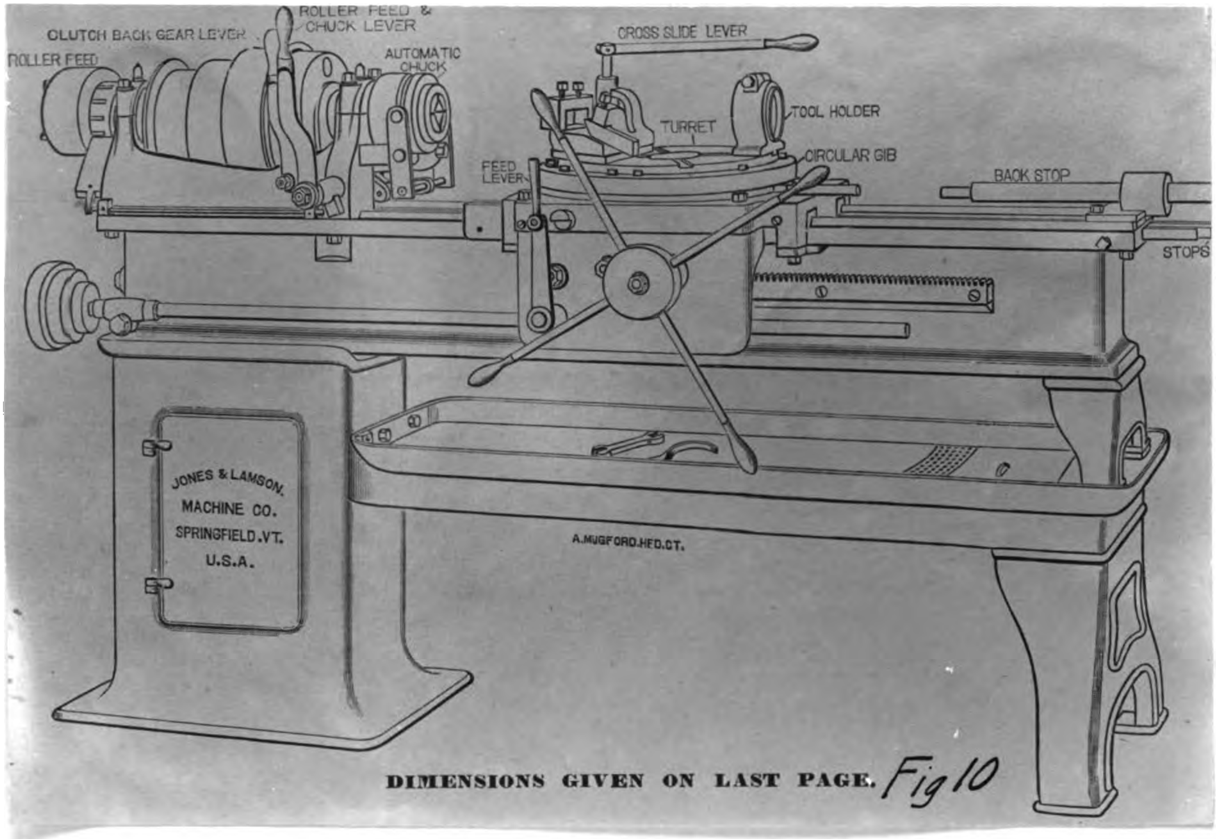

JONES & LAMSON MACH. CO.
SPRINGFIELD, VT. U.S.A.
BARTLETT & CO. N.Y.

Fig 9

The next step was the invention of the Flat Turret itself. The first Flat Turret Lathe made in 1891 is shown in Figure 10. The head stock, as will be seen, is practically the same as that in Figure 9, but the flat turret makes of the machine a vastly more useful tool for general machine shop work. For the first time it becomes possible to turn long pieces like shafting, spindles, etc., from the bar, with an accuracy and rapidity heretofore impossible. This marks

the first step taken by the turret lathe in getting away from the restricted field of the old fashioned "Screw Machine".



DIMENSIONS GIVEN ON LAST PAGE. Fig 10

This increase in the usefulness of the turret lathe was not due alone to the form of the turret, but also to the tools that were mounted on it. The original outfit of tools is shown in Figure 11. The important feature is the use of the back rested turners, of which two are shown. These tools embody the principles now universally used in all turret machines for doing bar work. The prime feature of improvement was the provision of adjustable blade and back rest in the same holder, to which the severe strains of cutting were

thus confined, without permitting deflection and lack of truth in even the slenderest turning.

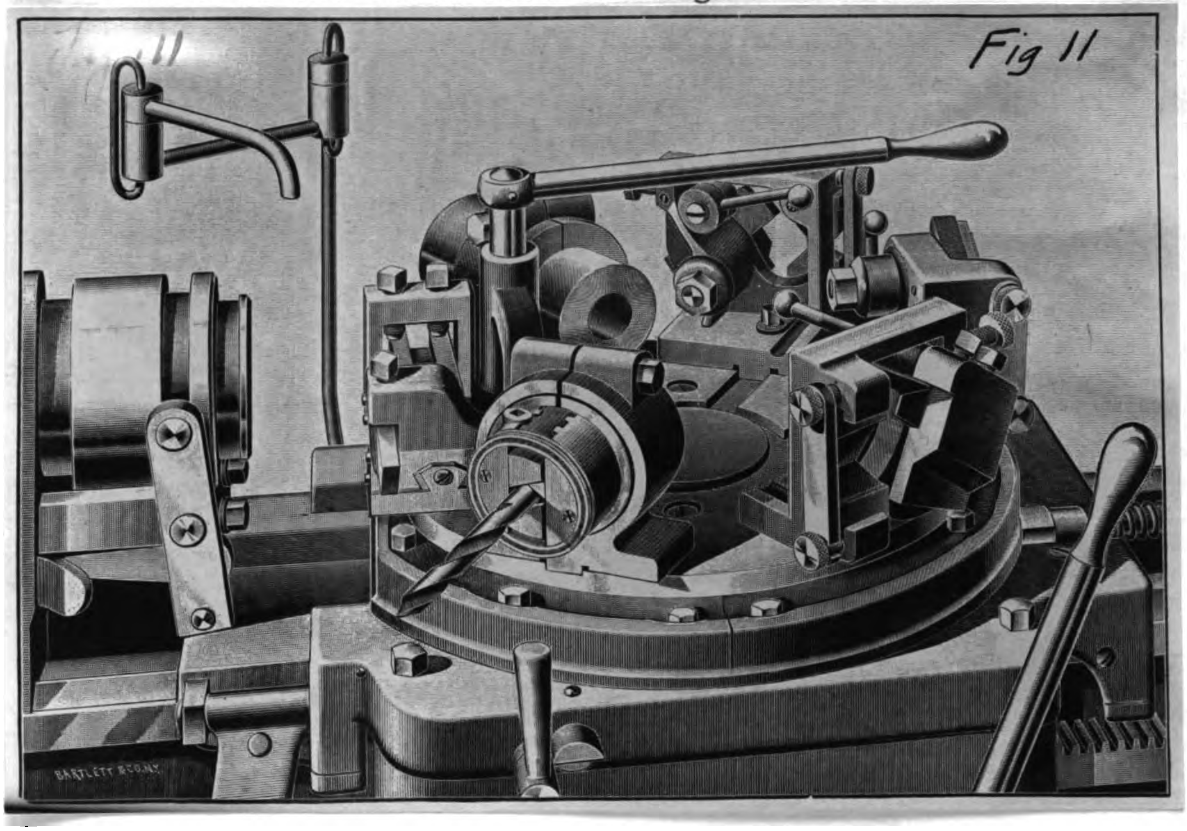

BARTLETT & CO. N.Y.

Fig 11

Figure 12 shows the chasers designed by Mr. Hartness in 1894 for the first automatic opening die of the kind now generally used. The accuracy of these chasers, as is well known, depends on the dies' bearing back of the cutting edge at the rear end of the chaser so as to give the tool a nut and lead screw effect in the bearing of the chaser on the completed portion of the thread. This has made possible the cutting of accurate threads by other means than the lead screw of the lathe.

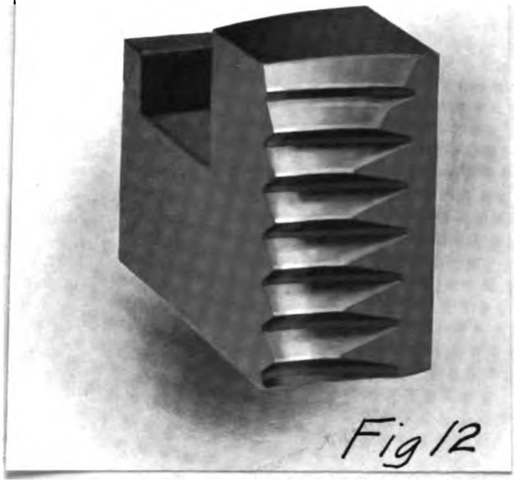


Fig 12

Figure 13 shows the cross sliding head design of the Flat Turret Lathe invented in 1904, and applied up to the present time with various modifications and improvements. Here again a radical change was made in design, which tremendously increased the effectiveness of the machine. By putting the cross movement between the head stock and the bed, instead of getting it by cross slide under the turret, the tool support was left as strong and as steady as on machines not provided with the cross motion. At the same time provision of the cross motion extended the field of the turret machine to chucking work of all kinds, where facing, recessing and similar operations required constant use of the cross feed. A large number of positive automatic stops are provided for both cross and longitudinal feed and a power feed is also applied to each.

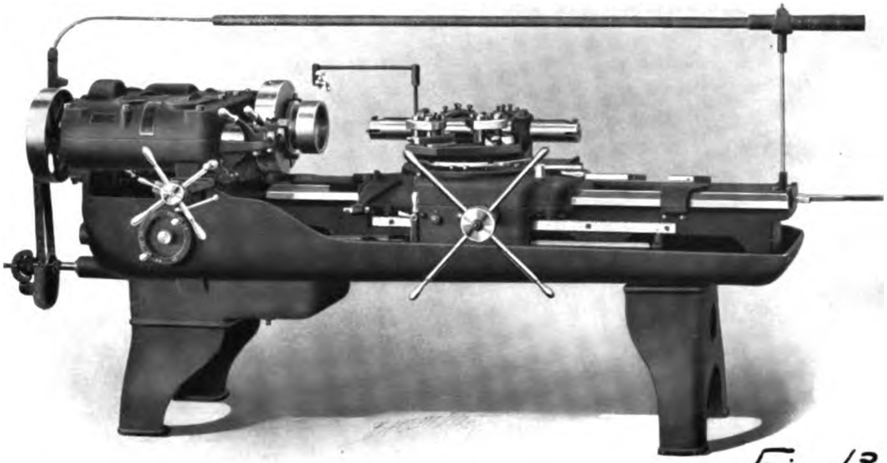
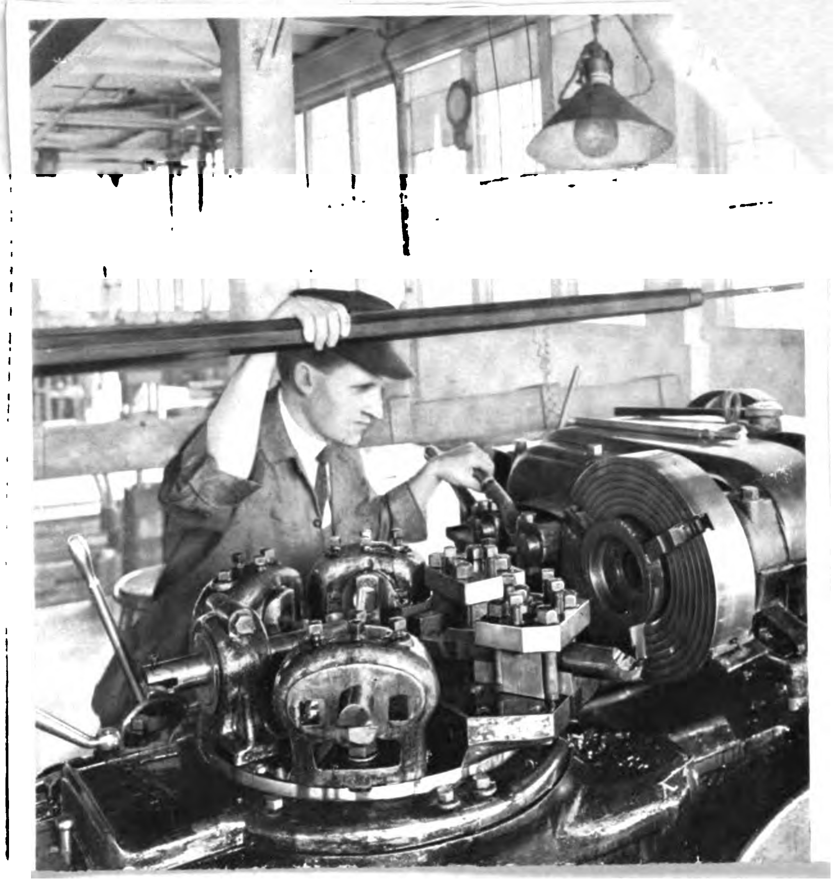


Fig. 13

Figure 14 shows the machine, as at present built, engaged on chucking work.



The last and one of the most important **advances** made by Mr. Hartness has been the design of the Double Spindle Flat Turret Lathe, shown in Figure 15. This machine was placed on the market in 1912. It is used for chucking work only. It has all the advantages of a single spindle machine, with the added advantage of doing two pieces in practically the same time as one piece had been previously done. There are two sets of tools, two working spindles and two pieces of work in operation at the same time.

The Double Spindle Flat Turret Lathe

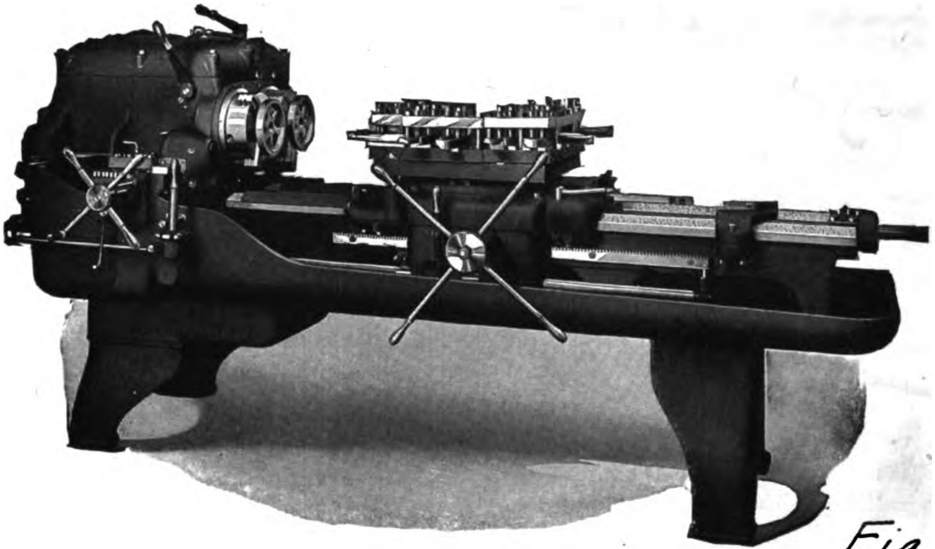


Fig 15

This covers the history of the turret machine in its various forms, so far as it relates to the Jones & Lamson Machine Company and its predecessor, the firm of Robbins & Lawrence, and the history of these firms has been, we are inclined to believe, practically the history of the turret

lathe itself from the very beginning.

There were very few tools in the United States in the eighteenth century, as the laws of Great Britain forbade the exporting of tools for working metals and manufacturing other tools. These laws also prohibited mechanics and artificers from going out of Great Britain to practice their trades. These conditions made it very difficult to obtain proper tools for machine building here. There are no reliable statistics as to the early tools, but on good authority it is stated that in the entire United States in 1838 there were but four planers. However, with these planers and a few lathes, drills, milling machines, etc., other machines could be built. An improvement on the drill was brought about by the invention of the boring mill by means of which larger bores may be turned. The work of the planer is materially aided by the shaper, a smaller machine in which the tool travels while the work remains stationary.[1]

Screw threads were first cut by dies and later by the lathe, making the work slow and tedious. In 1847 there was introduced the solid die (made by P. W. Gates) which had sectional threads for cutting, thus allowing the shavings to pass out between the sections. This same principle is used at the present time. The screw-die was considerably improved by William Sellers in 1857. Before 1867 most gear-wheels or

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1. Modern Industrial Progress, Chas. H. Cochrane.

cog-wheels were cast and used without machining, but in 1867 Sellers produced a gear-cutter which cut the teeth of large gears accurately. At the present time, all gears are cut with automatic machines at very low comparative cost, and with no difficulty as regards accuracy.

Cochrane defines a milling machine as "A modern tool for doing a variety of fine and accurate cutting, by means of rotating cutters". Punching machines are used to form holes by simply punching or forcing out part of the metal with dies. Drilling machines are made for a variety of special work, many of them having a number of drills all operating at the same time. Thick bars of steel may be cut by shearing-machines which operate rapidly, on the principle of gigantic shears, rather than by the old process of sawing. Rotary planers having series of cutting tools all operating at the same time by rotation over the surface of the work are also in use to some extent.

The modern bolt-making machine is almost entirely an automatic machine. This machine can be run by low-priced labor, and, with such, makes a more uniformly perfect bolt than was formerly made on regular machines by higher-priced labor. The attendant merely places a piece of stock in the grips of the machine, the projecting end is then squared off, the body of the bolt is turned, the screw-threads cut, the head beveled, the finished bolt cut off, and the bar moved

forward into a position for making another bolt. All this is done by the machine without attendance as long as the stock lasts.

Some twenty years or so ago new machines were developed more on the so-called "Happy thought" principle, the inventor working out his idea as best he could. Now the method of manufacturing new and improved machines is more systematized. When a new machine or improvement on an old one is wanted, the problem is turned over to engineers experienced in that line of work. They are given the benefit of all the ideas, "happy thoughts", and patented principles which are available to the persons desiring the new machine or improvement. They then proceed along the known scientific lines and with sufficient money are able to produce the required results.

When the new machine is completed it is put in operation and tested and the defects noted so that they may be remedied in the final product. When the machine reaches the point when it can be manufactured for commercial use, a great many special tools and jigs are manufactured so as to render the machines in part interchangeable, and also to aid in producing them at low cost. The larger the investment in special tools, the cheaper the machines can be made in large quantities.

The jig is the most common device used in making the parts of a machine so they will duplicate. It is simply an iron

frame-work for holding a piece that is to form a part of a machine. When the piece is rigidly secured in its jig, it may be accurately drilled through certain holes exactly located in the sides of the jig for that purpose. Instead of being drilled, it may, to be sure, be filed, machined or subjected to any action of any of the various tools, each one of which is limited and guided in its action by the form of the jig. When the casting is removed from the jig, it is sure to be an approximate duplicate of all others that have been operated on in the same manner in the same jig. In interchangeable manufacturing it is necessary that the parts be gauged and tested constantly in order to secure interchangeability.

This interchangeable system of machine manufacture originated in the United States, and abroad is generally known as the American system. The leading manufacturers of the Old World have not adopted it. The system is not only advantageous because of producing duplicate machines, but also because of the reduction of the cost of production. The making of the jigs is done by the higher-priced labor, but when that is done, the remainder of the work can be performed by the low-priced labor.

The American manufacturers of high grade tools produce them with extreme accuracy, measuring tools being made which will correctly determine differences as small as a twenty-thousandth of an inch. The tools of such concerns are sold

all over the world.

During the past twenty years automatic lathes have been extended so as to do a larger class of work. The turret lathe, a machine having a series of tools mounted on a revolving turret, has been applied to much larger and heavier work than was before attempted, and is operated with what is known as the magazine-feed. The magazine is made to contain a series of rough castings or drop-forgings which are to be turned in the lathe. The feed mechanism pushes these parts along, one at a time, while the lathe turns them up automatically, the attendant merely keeping the magazine supplied, the tools in condition, and removing the finished work.

The oil-tube drill was brought out about 1899, for use in drilling gun barrels. It consists of a drilling-tool having a small channel for leading the lubricating oil near to its point, so that it may be kept oiled during the work, without the constant use of an oil-can by the attendant. It has since been used in a great variety of drilling machines with a very considerable saving of labor.

The machining of very large castings or forgings, such as the magnet frames of large electric generators, is now accomplished through the use of portable tools, electrically driven, which can be applied readily to any portion of a heavy piece of work.

The development of cranes for transporting and moving heavy articles in the machine-shop has been a marked feature of American shops. In 1888, A. J. Shaw devised an independent, series-wound, reversing electric motor for each movement of the crane, and the principal defects of the mechanically driven cranes were eliminated.

The practice of using portable tools and bringing the tools to the work rather than the work to the tools is rapidly coming into more extended use. The portable tool which cannot be operated unless it is driven with an individual electric motor serves as an excellent example of what should be accomplished in making all machine tools as simple and useful as possible. Thus they are not arranged so as to be used in one particular location, but may be put anywhere as occasion demands without awkward connections to the line-shafting.

The United States census for 1900 shows that, excluding rolling-mills and the like, there are 397 establishments in the country manufacturing machines and tools coming under the classification of "Metal-Working Machinery". The capital invested was $55,000,000 and employment was given to 30,000 men. The chief materials used were mill supplies, and cost nearly $16,000,000, the value of the manufactured product being over $44,000,000.

Specializing has been the keynote of success in the

manufacture of American machine tools. Thus the man who took up one line was able to turn out a better product than the man who tried them all. American machinery leads the world today. In 1903 other nations bought $97,000,000 worth of manufactures of iron and steel. The first place now held by the United States is due largely to the continued exercise of constructive genius, backed by enterprising capital and assisted by helpful tariff laws.

Pratt and Whitney worked under Root, in Colt's Armory, and then went to the Lincoln shop in Hartford to make Lincoln tools, at that time the best made.[1] Later they started for themselves making an improved Lincoln type machine.

At this time the watch manufacturers were among the foremost in finding out new devices, or better uses for old devices, and they brought into use the hollow spindle, draw-back sleeve and collet. These were only used in the manufacture of the small watch parts and were not adapted to the manufacture of parts with quite large diameters. A number of years later Tyler, coming from a watch factory, put the collet in the Pratt and Whitney ten-inch toolmakers' lathe, which came into favor slowly but surely. It is only lately that the machine-shop managers understand that the hollow spindle and draw-back collet which give the small lathe such increased speed and power, make the collet indispensable in

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[1] How Machine Tools are Developed--John Randal in The American Machinist.

modern machine-shop equipment.

The early machine tools were of crude workmanship, most of the lathes being made partly of wood.[1.] When metal began to replace the wooden parts, architectural shapes and ornamentation were considered desirable in order to make the machine tools and also the machinery meet the taste of the people who used them. From England came the first good machine tools, and set the good example of simplicity of design.

Before the International Exhibition in 1851, the United States had made rapid strides in the production of machine tools, and was taking a high place in machine tool building.

In the first planers, the bed on which the work is attached was dragged back and forth by a chain. These were commonly used early in the thirties. At the time of the Vienna Exposition, the British engineers saw the broad feed cut on all the planers sent over from the United States and commented on it as "looking well" and "producing good effect" as though it had been put on merely for looks, not realizing that it was a principle well established in America and universally adopted as necessary to good work.

When Oliver Evans built the engines which pumped the water to the tank in the first water-works system in Philadelphia, the cylinders were bored out by a crude boring bar

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1. The Progress of the Mechanical Arts in Three-Quarters of a Century--Coleman Sellers in The American Machinist.

operated by hand, by means of levers attached to the bar, so that when men walked around the cylinder they propelled the cutting tools and forced the cutters through the cylinder. The inside of the cylinder then had to be filed out to make it fairly smooth. This operation took about a month.

In 1836 some locomotives were built in the Niles Works and the boring of the cylinders was done by a horizontal boring bar in a 36-inch lathe. To bore a cylinder of not over 15 inches diameter this process always took at least two days. It was not until about 1876 that much attention was turned to improving the method of boring metals. It was then realized that better results could be obtained, both as to quickness and quality of work, by making the roughing cut with a fine feed, removing as much metal as possible, and then making the finishing cut with a very broad feed, but with a light cut so that the tool might pass as far as possible through the metal without losing its cutting edge.

At the second annual exhibition held by the Franklin Institute in 1852, one of the things that attracted a good deal of attention among the judges was a lathe made by Rufus Tyler. The reasons for its attracting attention were its perfection of workmanship and improvements of construction. As to workmanship, it would compare favorably with the most perfect productions of the workshops of England and France. The sliding parts were easily moved, yet closely fitted. The

cast steel screw by which the front centre was moved, might be worked its entire length without a shake or inequality; and the centering seemed to be absolutely perfect. In making this lathe, simplicity of structure was especially sought for, as it was desired to produce a lathe adapted to general use. [1]

The shears, as they were called, or the bars on which the sliding head rested, were made supported on three feet properly spaced, leaving spaces between them unobstructed by cross bolts, and permitting the sliding head and rest to be taken out without detaching their holdfasts. The general shape of these two bars, which were connected by the feet, was that of an inverted horse-shoe.

The lathe was in most cases fastened to a table supported at each end by a case of drawers, leaving space between for the wheel and treadle. The wheel was made of cast iron, with curved arms to prevent breaking from contraction when casting. A smaller wheel for slower speed could be attached.

The first gear planer constructed in the United States was purchased by Bradford Machine Tool Company from The Gleason Works, Rochester, N. Y. It was sold by them to Orville Simpson Company, Winton Place, Cincinnati, Ohio, after twenty-five years use. It is still in use in the latter Company's shop.

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1. Improved Turning Lathe. Dr. T.P. Jones in The Journal of the Franklin Institute. Vol. 3, page 186.

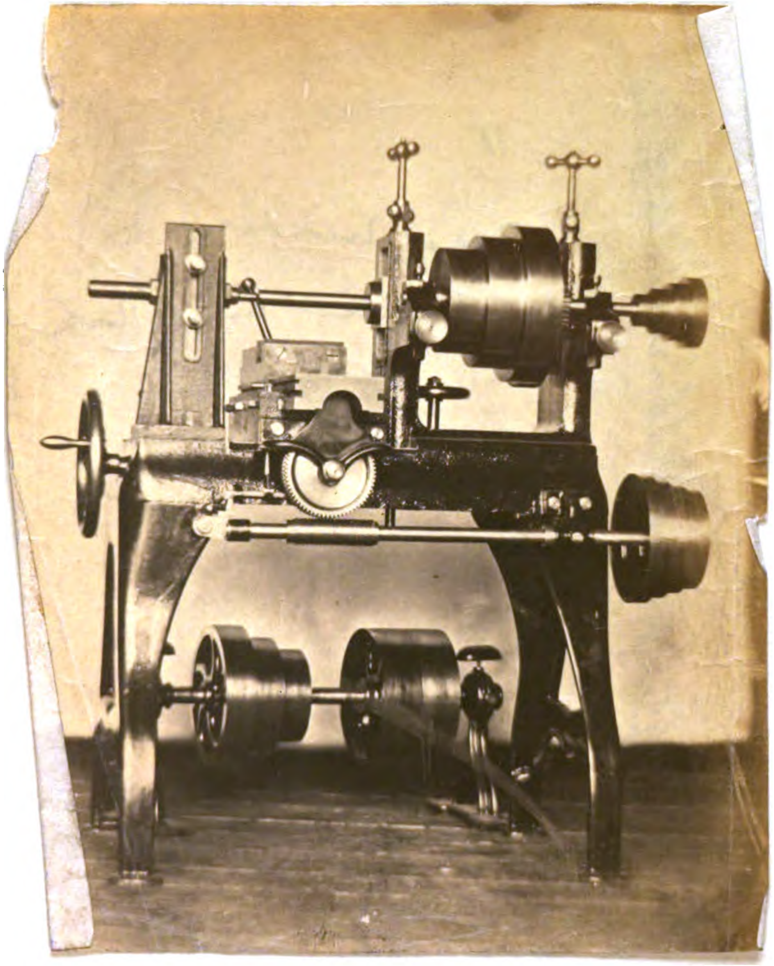
A Brief History of the Becker Brainard Milling Machine Company

In 1865 A. H. Brainard invented a bench vise known afterwards as the Union vise, of which in the succeeding years 40,000 were made and sold by the Union Vise Company of Boston. This vise of cast iron had its front jaw and base in one piece, the rear jaw having tenons on each side and travelling in grooves on the base. In its experimental stages these grooves and tenons were finished on a planer. The time required to fit the jaws of a four inch vise occupied the time of a good hand just about a whole day. Mr. Brainard's first attempt to save time and expense on this part of the vise was to rig up a milling attachment for an engine lathe. He fitted to the ways of the lathe a saddle having a circular prolongation dropping between the ways. This projection or cylinder was bored out to receive a corresponding cylinder casting in one piece with the bed above, which received a carriage having a movement of about eighteen inches at right angles with the lathe spindle and operated by a screw and crank. Primitive as was this device it demonstrated at once the superiority of milling irregular surfaces over planing, and search was begun at once for a suitable milling machine. He began studying up something to meet his requirements, when, in a small shop in New York City he happened to find a machine in use in which the work

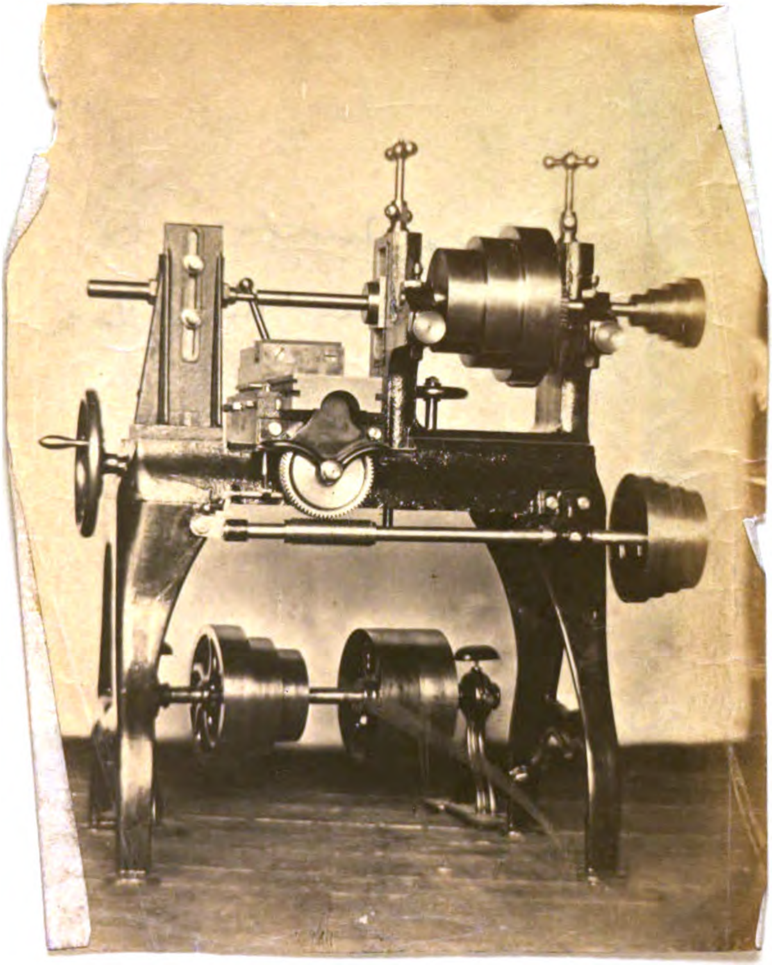
table was connected to a knee which travelled vertically upon the face of a standard or column. This attracted his attention and after careful examination he interviewed the maker, offering him an order, providing he would make such changes and improvements as Mr. Brainard suggested. These changes he was very reluctant to make, but finally agreed to build the machine as desired, by liberal consideration. This machine proved a valuable auxiliary for a short time, while the tools for manufacturing the vise were in progress, but as the front jaw and base needed to be grooved on both sides, it was early apparent that a double machine was a necessity for economical production. Therefore a milling machine with two independent adjustable heads was designed, or what would now be termed a Duplex machine, which proved a remarkable success. Meanwhile he was busy perfecting designs for a better and more powerful milling machine which was as successful as the duplex. While giving much time and study to perfecting the standard machine, it was two or three years before he thought of building machines for the market. When the project for building machines for sale was seriously entertained, he was opposed by some of his stockholders, one of whom, the treasurer of the company and the largest stockholder, inquired rather sarcastically "who wants milling machines", concluding his remarks by assuring Mr. Brainard that he would never live long enough to sell

one. The experiment was tried and truth compelled him to say that his efforts for the first year resulted in the sale of one milling machine only. The second year the sale was increased to nine, and by the winter of 1870-71 the milling machine business had assumed such proportion that the vise business was disposed of to the Backus Vise Company, Millers Fall, Massachusetts, which was soon afterwards merged into the Millers Falls Company. In April 1871 the works of the Union Vise Company were destroyed by fire and in June 1871 the Brainard Milling Machine Company was organized for the purpose of making milling and kindred machines alone. In 1899 the plant was again destroyed by fire, after which a new factory was erected upon the present site, and the company was reorganized and consolidated with the John Becker Manufacturing Company of Fitchburg. The name of the company was changed to the Becker Brainard Milling Machine Company, and the manufacture of Horizontal and Vertical milling machines has been successfully prosecuted to the present time.

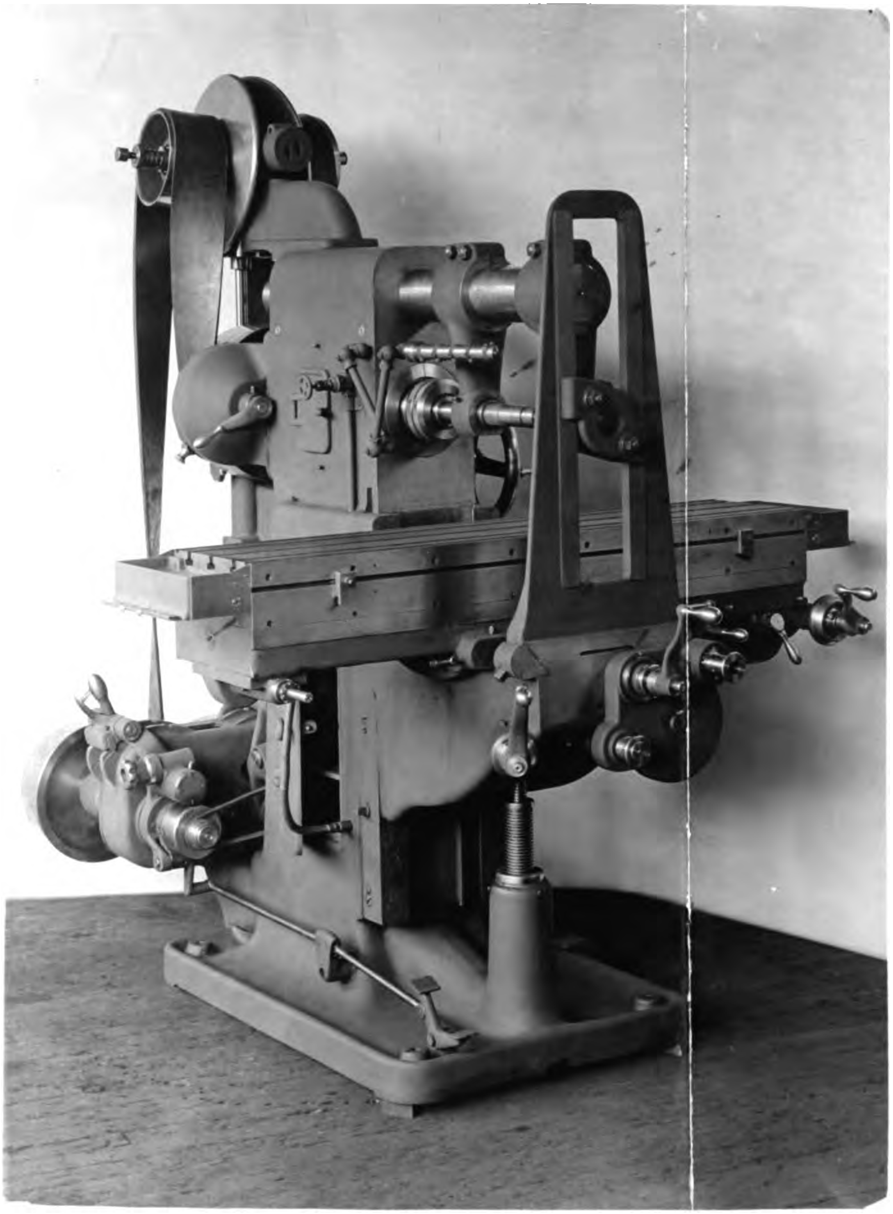
Machine tools, such as the lathe, planer, shaper, drill, etc., have undergone a process of development entirely independent of their cutting tools, and only after they had been made equal to the higher demands imposed upon them, were the same demands made upon the requisite tools. But



The First Model of the Becker Milling Machine.



The First Model of the Becker Milling Machine.



Latest Model of the Becker Milling Machine

with the milling machine, on the other hand, just the opposite has been the case.

In proportion, as the milling cutter proved to be a cutting tool of such supreme excellence for metal working, the milling machine adapted itself to this higher degree of development, so that the milling machine of recent years is the result and not the cause of the development of the milling cutter.

The milling cutter was brought into use some seventy years ago. It is said that an instrument-maker, Joseph Bramah, St. Giles, London, employed milling cutters in his workshop prior to the nineteenth century.[1.]

Notwithstanding the fact that about 1830 and for several decades subsequently, the milling cutter began to be employed, it still occupied a very modest place in the metal-working industry, being only made use of under quite exceptional circumstances, whilst the work which it turned out was regarded as decidedly expensive.

This was due to the erroneous principles on which the first makers of the milling cutters had set to work, and in consequence the milling cutter had a large number of fine teeth. They were made thus because of the idea that the greater the number of teeth on a milling cutter, the less the strain imposed upon each tooth during the portion of the

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1. Milling Machines and Milling Practice. D. DeVries. p.12.

revolution in which that tooth was actually working. From this view point the theory was correct, but the teeth were so numerous that the pitch was very fine, and the teeth shallow and, as a result, crowding and choking soon occurred, so that a large number of the teeth were rendered useless.

At this time the grinding machines had not been introduced, so that the milling cutter had to be sharpened before being hardened, and consequently a hardened cutter with really sharp teeth was practically an impossibility, the sharp edges being somewhat destroyed in the fire. When the cutter became dull it was necessary to treat it all over again with a great risk of cracking. For this reason the cutters were used as long as possible, long after they should have been sharpened, and consequently turned out a poor grade of work.

One of the earliest milling cutters in existence in America was made by Vaucauson, a French mechanic, who lived from 1709 to 1782.[1.] It has a hexagonal hole through the center and its profile is approximately that of the cutters for gear-wheel teeth. The pitch of the teeth is very small, the cutter resembling a saw, and the teeth are, moreover, irregular.

A Mr. Bodneer, of Manchester, England, is credited with having made a milling machine in 1824, but their general use in England dates from about 1880, which was since the emery

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1. Modern Milling Machines. J. G. Horner, Chapter I.

wheels were introduced for grinding the faces of the teeth.

Mr. Dixon, after careful inquiries, found that the use of the emery wheel for sharpening milling cutters was due to Mr. George Hannay, of Ulverstone, a brother of one of the firm of Schneider & Hannay, the original founders of the Barrow Steel Works.

The difficulties of the formation of the cutters were taken care of and then came the problem, fully as great, that of the construction of the machines. Both builders and users of milling machines have found their difficulties to depend on the following principles. The depth of a cut which can be taken by a tool diminishes with the increasing of the breadth of the cutting edge. Hence roughing tools are narrow and finishing tools are broad. As a result of this, milling cutters cannot take as deep cuts as single edged tools. And also when the width of milling cutters gets greater than two inches, the stresses are so severe, even with shallow cuts, that vibrations are set up which strain the machines and detract from the accuracy of the work.

Mr. E. G. Parkhurst in 1851 found what was probably the first milling machine ever constructed. He gathered the facts relating to it from Mr. Robert Johnson. The machine was first set to work in 1818 at a gun factory in Middletown, Conneticut, on a site known as Mill Hollow. At that time

the file was the principal tool used by the gun makers, and this new milling machine was used as a roughing tool so as to lessen the labor of the heavy filing, the finishing being left to be done by hand. It was applied only to plane faces, and did not include either curves or profiled forms. For several years it was a hand operated machine until a self-acting feed was added.

The bed plate of the machine was a rough casting measuring about 24 x 18 inches and 2 inches thick. A headstock, removed from an engine lathe, was bolted to the bed and carried a spindle with a square-tapered socket to receive the cutter spindle. The cutter itself was a plain one with filed teeth. It was about 1½ inches in diameter with a 1 inch face. The cone pulleys were of wood, having about a 2½ inch face, the largest one being 8 inches in diameter.

The work was traversed under the cutter by a hand crank which turned a pinion, which in turn engaged with a rack screwed on the under side of the table. The edges of the table were cut to fit the vee notches cut in the plugs carried in drilled holes in four uprights bolted to the bed, and secured by and rendered adjustable for wear by set screws. The work was gripped by a piece fitted with pinching screws having pointed ends.

Though the machine was very crude, the workmen took a great liking to it because it reduced the necessity of the

heavy file work.

The first great improvement of the milling machine was the substitution of provision for vertical adjustments of the spindle bearings for the fixed bearings of the first machines. This is supposed to have originated with Eli Whitney, of New Haven, Conneticut. There was very little progress made until the early fifties, though there were many milling machines in existence, most of them being made by firms for their own use. About this time these machines began to take rank with precision tools for duplicating pieces, before which they were used merely for roughing-down machines for the filers. Gang mills began to figure about this time, and an unsuccessful attempt was made to build a slabbing machine something like the modern planer.

In 1848, E. K. Root, superintendent of Colonel Colt's Armory at Hartford, brought out the Root machine. It was built on the Lincoln and earlier models, but the table was driven by a worm gearing into a spiral rack under the table. It embodied also a yielding clutch, with a hand lever for operating it, for the purpose of disengaging the driving cone pulley, so that the spindle could be stopped from the countershaft.

There was also an automatic knock-off, which stopped the machine instantly, leaving the table standing at any desired part of its traverse. Some of these machines have remained

in service fifty years

Soon after 1850 the Howe machine was brought out, and then the Ames Manufacturing Company, of Chicopee, Massachusetts, made many machines, one being a modified Howe, designed by C. McFarland. These machines greatly resembled the Lincoln miller, designed by F. A. Pratt in 1854, a type on which more machines have been made than on any other. Its distinguishing feature was the substitution of a screw feed in place of the pinion and rack feed. The quick return was effected by hand.

Between 1860 and 1866, especially during the Civil War, the hundreds of thousands of small arms turned out in government and private factories gave the opportunity for improvement of milling machines, and they became firmly established as precision tools. At that period the manufacture of sewing machines was increasing rapidly, and so after 1863 nearly all the armory-milling machines, which were being abandoned in consequence of the closing of the war, were purchased by the sewing-machine manufacturers.

Up to this period, forty-five years after the invention of the milling machine, there was but one type in use, the modern representative of which is the Lincoln miller. All the machines had horizontal spindles and housings adjustable vertically. Most had tailstocks also, but the Root introduced an overhanging arm with movable centre, in place of

the tail stocks. They had back gears and compound tables. The legs in every case were of the A form, in lathe fashion. The pillar and knee machine had not appeared, nor the vertical spindle machines, nor any successful slabbing miller, nor rotary face mills with inserted teeth, nor any cutters of large dimensions.

About the first machine built exclusively for milling was the so-called Lincoln miller built by the Pratt & Whitney Company, Hartford, Conneticut.[1.] It consists of a bed carrying the equivalent of the head stock and tail stock of a lathe, with means of rotating the cutter arbor, which is carried by the head stock spindle, and steadied and supported by the tail stock. There is also provided a lathe upon which the work can be fastened either directly, or by means of a vise, and the automatic feed across the machine at right angles to, and below, the cutter arbor. This is simply the milling attachment in the lathe transferred to a machine designed to do nothing but milling.

In the United States in about 1870, Brown & Sharpe first manufactured milling cutters of a new type, the coarse pitched cutter, and as a natural result with much deeper teeth, thus making it possible to cut deeper. This became generally known in Europe during the Exhibition in Vienna in 1873. At first the Europeans were very much against this new form of cutter, but at the World's Exhibition in Philadelphia in

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1. Machine Shop Work. F. W. Turner, p. 133.

1876 there was exhibited to the European experts a universal and many-sided application of the coarse pitched milling cutter.

The first milling machine made by the firm of J. R. Brown, now known as Brown & Sharpe, was patented February 21, 1865.

The milling machine would never have attained its present development but for the growth of the emery grinder. Its era dates from that period, notwithstanding the fact that the milling cutter itself is more than a century old and its milling machine about eighty years old. In the older methods the temper of the cutters had to be drawn for sharpening, and re-hardened, all of which is inconsistent with accuracy and economy. It is to the emery wheel that we also owe the displacement of cast gears by cut ones. The old cutters were not accurate enough for such work, nor would they retain their shape umimpaired by grinding.

The types of milling machines, ranging from plain to universal, are as varied as the classes of work which are done by milling. The types overlap each other, making a strict classification impossible, but a fairly satisfactory one is as follows:

1. Lincoln millers.
2. Pillar and knee machines with horizontal spindles.
3. Vertical spindle machines and profiling

machines.

4. Plano millers and slabbing machines.

5. Special machines for gear-cutting, etc.

Great changes in the design of machine tools have been made during the past twelve years, on account of the heavier service demanded by the general use of high speed tools.

The changes in design due to high speed steels have been rather in the direction of strength and control than in departure from established forms which are the result of a process of evolution, and the object of this discussion has been to trace the general history of the development of machine tools to their present forms.

Approved,

John G. D. Mack

Professor of Machine Design

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